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POTENTIAL OF CITRONELLA OIL AS RODENT REPELLENT MEASURED AS AVERSION TO FOOD

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ABSTRACT

Repellents act by stimulating the primary or secondary defense mechanisms, causing the food to be rejected. Mature and healthy house rats, *Rattus rattus*, of both the sexes, were exposed to 5, 10, and 20% citronella oil applied as paint in laboratory pens in choice with no oil. Each concentration was applied through 3 different modes of application (daily, once and alternatively in a week). Repellent effect of oil was assessed by comparing food consumption from treated sides with those of untreated sides. The food consumption was recorded over a period of 4 days. In overall, food consumption was significantly ($p \leq 0.05$) lower from treatment side compared to the untreated side indicating significant repellent effect of the oil. Repellent effect of oil, however, did not differ significantly between the two sexes. Significant difference in average percent repellent effect between 5 and 10% concentrations was observed when oil was applied daily in both female and male rats with higher effect of treatment at 10%. The studies revealed higher potential of daily application of citronella oil as paint in repelling away rats of both sexes.

Key words: Citronella oil, food consumption, paint, *Rattus rattus*, repellency

INTRODUCTION

Rodents belong to one of the most interesting groups of mammals. The damage and economic losses caused by rodents in various field crops, horticulture and forestry, poultry farms, rural and urban dwellings and storage facilities range from 2 to 15% in India (Parshad, 1999; Singla and Babbar, 2010). Rodents also transmit a number of diseases to humans and animals (Singla *et al.*, 2008a,b, 2013a, 2014a,b). Several commonly used rodenticides and pesticides present a risk of primary and secondary poisoning in non-target species. Thus, the development of a repellent capable of mediating avoidance behaviour through volatile cues is desirable. Plants produce a wide range of compounds that act as a defense against herbivory. The development and use of locally available plant products with repellent activity is thus an alternative eco-friendly strategy for rodent control.

Renewed interest in plant-based repellents was generated after the US Environmental Protection Agency added a rule to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) in 1986 exempting compounds considered to be minimum risk pesticides (Barnard, 1999). Substances that cause insects and other animals to move away from the source are called repellents. All plants produce and store secondary metabolites which are unimportant for primary or energy metabolism of a plant. Most secondary metabolites interfere with basic molecular targets of animals

or microbes and thus provide the plants adequate protection against a multitude of enemies. Repellents are relatively inexpensive and a practical means of protection against a number of pests, especially when other control measures are not feasible. Mills and Munich (1942) defined rat repellents as the substances placed in runways of rats that prevent them from going where they wish. These may include any object or device or a chemical substance which by touch, sound, colour, taste or odour will ward off the animal or prevent an animal from feeding or gnawing. Singla (2005) studied the effect of spiny twigs of *Acacia* in burrow desertion by rodents.

Botanicals have advantages over broad-spectrum conventional pesticides as they affect only target pest and closely related organisms, are effective in very small amounts, decompose quickly, and provide residue-free food and a safe environment to live. When incorporated into IPM programmes, botanical pesticides greatly decrease the use of conventional pesticides or can be used in rotation or in combination with other pesticides, potentially lessen the overall quantities applied and possibly mitigate or delay the resistance development in pest populations (Khater, 2012).

Citronella oil is a volatile oil which is distilled using steam from the greenish blue, lemon-scented leaves and stem of the plant *Cymbopogon* spp. and the main constituents are citronellal and geraniol. Citronella oil is a colourless or light yellow liquid with a characteristic woody, grassy or lemony odour. The essential oil from *C. winterianus* has repellent properties (Clay *et al.*, 2005), but relatively little work has been done on plant-derived repellents compared to other aspects of rodent control. Singla *et al.* (2013b, 2014c) studied the potential of eucalyptus oil as repellent against *R. rattus*. Singla and Parshad (2005) studied the potential of neem-based product as repellent against *R. rattus*. No study has been made on evaluating the potential of citronella oil as repellent against rodent pests. The present study was carried out to evaluate the potential of citronella oil as repellent against *R. rattus*, a predominant rodent pest species.

MATERIALS AND METHODS

The present work was carried out in the Department of Zoology, Punjab Agricultural University (PAU), Ludhiana (India) during the year 2012-13. Citronella oil was procured from the New Crops Laboratory, Department of Agronomy, PAU, Ludhiana. The rats (*R. rattus)* of both sexes were trapped with the help of multi-catch rat traps from poultry farms in and around the Ludhiana (India). In laboratory, the rats were acclimatized individually in cages of 36×23×23 cm size for 15-20 days before the start of experiment. Food and water were provided *ad libitum*. Food consisted of a mixture of mashed wheat, powdered sugar and groundnut oil (WSO) in 96:2:2 ratio. The metallic trays were kept under each cage for the collection and disposal of urine and faeces. Animals were used and maintained as per the guidelines of Institutional Animal Ethics Committee, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana (India). After acclimatization, healthy and mature rats of both sexes were weighed and selected for further studies.

A total of four laboratory pens, each of 252 × 100 × 72 cm size, were used for each experiment. Each laboratory pen consisted of 3 chambers of equal size. One rat was released in each chamber. Each chamber in a laboratory pen, on its opposite facing sides, was connected to 2 small nest boxes of 20 × 15 × 15 cm size each by means of holes of 6 cm diameter. Each rat had free access to both the two nest boxes attached on opposite sides of a chamber. Three different concentrations of citronella oil *i.e.*, 5, 10 and 20% were tested. These concentrations were prepared by dissolving citronella oil in isopropyl alcohol. Each concentration was tested on 12 rats (6 of each sex). Treatment was given in the nest box of one side of a chamber of laboratory pen. Citronella oil was applied as paint on all the inner sides of the nest box using cotton swab dipped in oil. Rats were exposed to each concentration of oil through three different modes of application *i.e.*, applied daily (from monday to thursday), applied once a week (on monday only) and applied alternatively (on monday, tuesday and thursday). Weighed quantity (20 g) of food i.e., WSO taken in a bowl was

placed in both the nest boxes of a chamber. Simultaneously 6 rats of either sex were exposed to the vehicle isopropyl alcohol applied daily in choice with no vehicle. Repellent effect of vehicle was determined based on consumption of food from treatment and untreated sides of a chamber for 4 days.

The repellent effect of oil was assessed on the basis of food consumption by rat from the food bowls kept in 2 nest boxes of a chamber in a laboratory pen. Food consumption was recorded daily after every 24 hr from both treated and untreated sides for 4 days in a week *i.e.* from tuesday to friday to determine mean daily food consumption [g 100 g^{-1} body weight (bw)]. Based on mean daily food consumption data, percent repellent effect was determined using the formula given described by Singla *et al.* (2014c).

The values were determined as mean ± SD. The data on food consumption for 2 sexes, 3 concentrations of oil, 3 modes of applications, 4 days of application, and from treatment and untreated sides was collected using factorial experiments in completely randomized design. Analysis was done using general linear model (GLM) in SAS 9.3. All pair wise treatment comparisons were made using Tukeys' HSD test at 5% level of significance.

RESULTS AND DISCUSSION

In all, significantly ($p<0.05$) low consumption of food was noticed from treatment side as compared to untreated side at all the 3 concentrations and modes of application (Tables 1-3) indicating repellent effect produced by citronella oil when applied as paint. No significant difference in average percent repellent effect of all the 3 concentrations of oil was observed between male and female rats at all the 3 modes of application. The difference in mean daily food consumption by rats from untreated side (8.62 ± 3.48 g 100 g^{-1} bw) of a chamber and side treated (7.20 ± 3.17g 100 g^{-1} bw) with isopropyl alcohol provd non-significant indicating no repellent effect of the vehicle.

Table 1: Food consumption in response to application of 5% citronella oil as paint by *Rattus rattus*

Mode of application	Days of application	Mean daily food consumption (g 100 g^{-1} bw)			
		Female rats (n = 6) (Body wt = 128.33 ± 8.97 g)		Male rats (n = 6) (Body wt = 148.33 ± 12.13 g)	
		Treatment side	Untreated side	Treatment side	Untreated side
I	Day 1	14.78 ± 2.75^{a}	16.34 ± 4.77^{a}	8.01 ± 4.08^{a}	12.04 ± 2.06^{b}
	Day 2	17.11 ± 1.60^{a}	17.57 ± 3.79^{a}	7.59 ± 3.44^{a}	12.66 ± 3.82^{b}
	Day 3	13.68 ± 4.05^{a}	15.89 ± 4.46^{a}	8.70 ± 4.08^{a}	13.66 ± 5.41^{a}
	Day 4	10.79 ± 3.88^{a}	13.25 ± 5.59^{a}	11.07 ± 2.50^{a}	11.68 ± 4.41^{a}
	Average	14.09 ± 2.27^{A}	15.74 ± 1.55^{A}	8.84 ± 1.34^{A}	12.51 ± 0.75^{B}
II	Day 1	6.18 ± 3.76^{a}	10.78 ± 6.25^{a}	5.52 ± 3.43^{a}	8.58 ± 4.35^{a}
	Day 2	7.09 ± 2.86^{a}	10.22 ± 5.87^{a}	8.25 ± 4.15^{a}	5.18 ± 1.03^{a}
	Day 3	11.11 ± 5.01^{a}	9.62 ± 5.50^{a}	7.18 ± 5.36^{a}	9.76 ± 6.90^{a}
	Day 4	8.08 ± 3.52^{a}	5.70 ± 7.31^{a}	6.55 ± 1.89^{a}	4.81 ± 3.77^{a}
	Average	8.11 ± 1.85^{B}	9.08 ± 1.99^{BC}	6.87 ± 0.99^{A}	7.08 ± 2.13^{A}
III	Day 1	9.48 ± 4.56^{a}	10.38 ± 4.53^{a}	6.06 ± 2.71^{a}	9.19 ± 4.85^{a}
	Day 2	6.89 ± 5.72^{a}	8.96 ± 1.77^{a}	3.37 ± 2.21^{a}	5.77 ± 1.12^{a}
	Day 3	5.62 ± 2.96^{a}	6.75 ± 3.95^{a}	3.24 ± 3.69^{a}	7.24 ± 3.43^{a}
	Day 4	5.64 ± 5.04^{a}	12.38 ± 4.3^{b}	5.28 ± 5.18^{a}	11.85 ± 3.67^{b}
	Average	6.90 ± 1.57^{B}	9.61 ± 2.05^{C}	4.48 ± 1.21^{B}	8.51 ± 2.27^{A}

Values are mean ± SD, I = daily, II = once a week, and III = alternatively.

The values with similar superscripts in a column for 4 days of application (a or b) and for average values (A, B or C) at all the 3 modes of application indicate no significant difference. Values with different superscripts in a row for each sex for 4 days of application (a-b) and for average values (A–C) at each mode of application indicate significant difference at $p \leq 0.05$.

The average mean daily food consumption by male rats was significantly low from treatment side when 5% oil was applied daily and alternatively (Table 1). However when oil was applied once a week the mean daily food consumption by male rats was not significantly lower from treatment side indicating low repellent effect of oil in this mode of application. This may be due to the less persistence of oil odour which was applied only on day 1 of week. In female rats, however, the average mean daily food consumption was significantly lower from treatment side when citronella oil was applied alternatively. No significant difference was seen in average food consumption between treatment and untreated sides when oil was applied daily or once a week. When oil was applied once a week, the food consumption significantly varied from treatment side on days 3 and 4 in female rats and on days 2 and 4 in male rats as compared to that observed on untreated side.

In male rats, average percent repellent effect with 5% citronella oil applied once a week was significantly lower than that observed when the oil was applied alternatively and non-significantly low when the oil was applied daily (Fig. 1). In female rats, no significant difference was found in repellent effect among all the 3 modes of application. Apparently the repellent effect was non-significantly high when oil was applied alternatively in both male (45.62%) and female (32.94%) rats. At 5% concentration of citronella oil, no significant difference was found in repellent effect between male and female rats on all the 4 days of application when the oil was applied once a week and alternatively. However when the oil was applied daily, the repellent effect was significantly high in male rats (41.2%) from that in female rats (10.29%) on day 2 of application (Table 4).

The average mean daily consumption of food by male rats was significantly ($p \leq 0.05$) low from treatment side when 10% oil was applied daily and alternatively (Table 2), however, when the oil was applied once a week, the average mean daily food consumption by male rats was non-significantly low from treatment side indicating low repellent effect of the oil at this mode of application. At this mode of application, the food consumption was not significantly higher from the treatment side on days 3 and 4. This may be due to the less persistence of the odour of the oil which was applied only on day 1 of the week. In female rats, however, the average mean daily

Table 2: Food consumption in response to application of 10% citronella oil as paint by *Rattus rattus*

Mode of application	Days of application	Mean daily food consumption (g 100 g^{-1} bw)			
		Female rats (n = 6) (Body wt = 130.00 ± 5.77 g)		Male rats (n = 6) (Body wt = 148.33 ± 10.67 g)	
		Treatment side	Untreated side	Treatment side	Untreated side
I	Day 1	5.75 ± 2.30^{a}	10.19 ± 3.78^{b}	3.15 ± 2.09^{a}	7.51 ± 3.70^{b}
	Day 2	3.14 ± 3.95^{a}	9.77 ± 3.69^{b}	3.92 ± 2.75^{a}	8.48 ± 3.10^{b}
	Day 3	4.33 ± 2.65^{a}	8.78 ± 3.15^{b}	2.30 ± 1.30^{a}	7.85 ± 3.35^{b}
	Day 4	2.05 ± 1.85^{a}	12.44 ± 1.85^{b}	4.45 ± 2.90^{a}	7.24 ± 2.68^{b}
	Average	3.81 ± 1.37^{A}	10.29 ± 1.34^{B}	3.45 ± 0.81^{A}	7.77 ± 0.46^{B}
II	Day 1	5.34 ± 6.94^{a}	14.55 ± 4.31^{b}	4.57 ± 1.38^{a}	6.80 ± 2.01^{b}
	Day 2	6.75 ± 3.55^{a}	9.20 ± 2.97^{a}	5.51 ± 2.85^{a}	7.82 ± 1.88^{a}
	Day 3	7.19 ± 2.66^{a}	6.75 ± 2.21^{a}	5.68 ± 1.85^{a}	4.88 ± 0.89^{a}
	Day 4	5.18 ± 2.57^{a}	8.45 ± 3.84^{a}	5.41 ± 3.36^{a}	5.31 ± 2.49^{a}
	Average	6.11 ± 0.87^{A}	9.73 ± 2.91^{AB}	5.29 ± 0.42^{A}	6.20 ± 1.17^{AB}
III	Day 1	6.31 ± 2.99^{a}	10.92 ± 2.79^{b}	4.00 ± 2.88^{a}	10.70 ± 2.36^{b}
	Day 2	5.84 ± 1.60^{a}	7.89 ± 3.03^{a}	2.85 ± 2.23^{a}	8.78 ± 2.47^{b}
	Day 3	6.84 ± 4.23^{a}	6.71 ± 2.71^{a}	3.87 ± 1.39^{a}	7.46 ± 3.78^{a}
	Day 4	2.97 ± 2.64^{a}	6.35 ± 2.92^{b}	5.86 ± 3.19^{a}	6.20 ± 3.44^{a}
	Average	5.49 ± 1.49^{A}	7.96 ± 1.79^{AB}	4.14 ± 1.08^{A}	8.28 ± 1.66^{B}

Values are mean ± SD, I = daily, II = once a week, and III = alternatively. The values with similar superscripts in a column for 4 days of application (a or b) and for average values (A, B, or C) at all the 3 modes of application indicate no significant difference. Values with different superscripts in a row for each sex for 4 days of application (a-b) and for average values (A–C) at each mode of application indicate significant difference at $p \leq 0.05$.

Table 3: Food consumption in response to application of 20% citronella oil as paint by *Rattus rattus*

Mode of application	Days of application	Mean daily food consumption (g 100 g^{-1} bw)			
		Female rats (n = 6) (Body wt = 130.00 ± 5.77 g)		Male rats (n = 6) (Body wt = 131.66 ± 13.43 g)	
		Treatment side	Untreated side	Treatment side	Untreated side
I	Day 1	5.15 ± 3.16^{a}	10.05 ± 2.61^{b}	3.35 ± 2.01^{a}	7.95 ± 2.59^{b}
	Day 2	5.60 ± 2.90^{a}	8.58 ± 1.74^{a}	5.96 ± 2.87^{a}	10.95 ± 4.57^{a}
	Day 3	12.63 ± 2.56^{a}	15.09 ± 1.87^{a}	10.96 ± 1.09^{a}	12.21 ± 1.54^{a}
	Day 4	3.96 ± 3.40^{a}	10.37 ± 2.25^{b}	4.24 ± 1.59^{a}	8.92 ± 2.40^{b}
	Average	6.83 ± 3.39^{A}	11.02 ± 2.44^{A}	6.12 ± 2.94^{A}	10.00 ± 1.66^{A}
II	Day 1	5.28 ± 1.34^{a}	12.17 ± 2.50^{b}	7.32 ± 1.20^{a}	13.05 ± 4.31^{b}
	Day 2	8.16 ± 4.91^{a}	7.41 ± 3.44^{a}	6.71 ± 3.42^{a}	11.87 ± 3.14^{b}
	Day 3	11.30 ± 6.00^{a}	14.31 ± 2.10^{a}	11.80 ± 1.10^{a}	10.84 ± 2.43^{a}
	Day 4	5.30 ± 3.81^{a}	11.15 ± 5.95^{a}	8.43 ± 3.59^{a}	7.23 ± 2.89^{a}
	Average	7.51 ± 2.48^{A}	11.26 ± 2.49^{A}	8.56 ± 1.96^{A}	10.74 ± 2.17^{A}
III	Day 1	5.94 ± 2.97^{a}	8.30 ± 3.86^{a}	4.00 ± 1.26^{a}	7.73 ± 3.26^{b}
	Day 2	4.53 ± 2.36^{a}	7.86 ± 2.13^{b}	3.59 ± 1.97^{a}	7.70 ± 2.80^{b}
	Day 3	9.79 ± 3.86^{a}	10.46 ± 3.70^{a}	7.74 ± 2.80^{a}	5.69 ± 2.86^{a}
	Day 4	15.52 ± 3.22^{a}	10.57 ± 3.03^{b}	6.81 ± 3.32^{a}	6.84 ± 3.32^{a}
	Average	8.94 ± 4.25^{A}	9.29 ± 1.22^{A}	5.53 ± 1.77^{AB}	6.99 ± 0.83^{B}

Values are mean ± SD, I = daily, II = once a week, and III = alternatively.

The values with similar superscripts in a column for four days of application (a or b) and for average values (A, B, or C) at all the 3 modes of application indicate no significant difference. Values with different superscripts in a row for each sex for 4 days of application (a-b) and for average values (A–C) at each mode of application indicate significant difference at $p \leq 0.05$.

consumption of food was significantly ($p \leq 0.05$) low from treatment side when the citronella oil was applied daily (Table 2). No significant difference was found in average food consumption between treatment and untreated sides when the oil was applied once a week and alternatively. When the oil was applied once a week, the food consumption was non-significantly different from treatment side on day 3 in female rats and on days 3 and 4 in male rats as compared to that observed on untreated side. Food consumption by female rats was also non-significantly high from treatment side on day 3 when the oil was applied alternatively.

In male rats, the average repellent effect with 10% citronella oil applied once a week (25.25%) was significantly low from that observed when the oil was applied daily (52.88%) or alternatively (41.62%) [Fig. 1]. In female rats, when the oil was applied once a week, the average repellent effect was significantly low (38.25%) from that observed when oil was applied daily (61.4%). The same was non-significantly low from that observed when oil was applied alternatively (40.77%). At 10% concentration of citronella oil, no significant difference was seen in repellent effect between male and female rats on the all the 4 days of application when oil was applied once a week. However, when the oil was applied daily, the repellent effect was significantly high in female rats (82.41%) than those in male rats (47.99%) on day 4 of application (Table 4). When the oil was applied once a week, the repellent effect was significantly high in female rats (68.41%) from that in male rats (30.40%) on day 1 of application. The average mean daily consumption of food by male and female rats was not significantly different from treatment side at all the three modes of application of 20% citronella oil (Table 3). When the oil was applied once a week, the food consumption was not significantly different from treatment side on days 3 and 4 in male rats and on day 2 in female rats. When oil was applied alternatively, the food consumption was not significantly different from treatment side on day 3 in male rats and significantly high on day 4 in female rats. This may again be due to the decreased persistence of the odour of oil with time.

No significant difference was found in average percent repellent effect of 20% citronella oil in male and female rats at all the three modes of application. Also no significant difference in average

Table 4: Percent repellent effect with citronella oil applied as paint using three different concentrations against *Rattus rattus*

Mode of application	Days of application	Percent repellency					
		5%		10%		20%	
		Female rats (n = 6)	Male rats (n = 6)	Female rats (n = 6)	Male rats (n = 6)	Female rats (n = 6)	Male rats (n = 6)
I	Day 1	15.70±19.22^{a}	37.88±31.71^{ab}	39.15±26.12^{a}	46.04±36.34^{ab}	50.73±21.35^{a}	51.05±33.52^{a}
	Day 2	10.29±10.34^{a}	41.20±28.93^{b}	71.81±34.21^{a}	58.02±27.87^{ab}	21.17±36.60^{a}	27.40±23.63^{a}
	Day 3	19.88±17.85^{a}	42.16±32.20^{ab}	52.24±19.51^{a}	59.48±33.19^{ab}	16.02±12.78^{a}	11.02±7.52^{a}
	Day 4	23.59±23.14^{a}	12.94±9.22^{ab}	82.41±15.71^{a}	47.99±35.39^{b}	56.97±38.92^{a}	52.24±15.10^{a}
	Mean	17.36±4.94^{A}	33.54±12.00^{AB}	61.40±16.79^{A}	52.88±5.93^{A}	36.22±17.85^{A}	35.42±17.22^{A}
II	Day 1	39.16±26.89^{a}	40.19±35.85^{a}	68.41±33.19^{a}	30.40±22.51^{b}	54.71±15.02^{a}	36.57±21.03^{a}
	Day 2	32.11±32.86^{a}	16.26±23.41^{a}	29.69±27.60^{bc}	31.63±33.77^{ab}	19.15±29.71^{ab}	15.03±17.67^{b}
	Day 3	23.77±27.90^{a}	26.17±37.15^{a}	11.39±16.34^{b}	5.86±11.79^{ab}	24.61±34.59^{ab}	4.67±6.97^{b}
	Day 4	12.90±22.13^{a}	5.23±7.41^{a}	44.60±23.39^{ac}	33.14±26.26^{ab}	50.32±32.36^{a}	15.33±15.52^{b}
	Mean	26.98±9.78^{A}	21.96±12.86^{A}	38.52±20.88^{B}	25.25±11.24^{B}	37.19±15.51^{A}	17.90±11.60^{A}
III	Day 1	17.41±27.93^{a}	32.09±33.58^{a}	43.74±17.46^{a}	58.33±27.83^{ab}	28.60±22.63^{ac}	39.82±10.72^{a}
	Day 2	33.50±40.13^{a}	44.61±32.15^{a}	27.75±21.69^{a}	61.75±34.63^{b}	47.54±24.30^{c}	53.37±18.44^{ac}
	Day 3	25.56±35.15^{a}	57.84±41.46^{a}	29.87±34.35^{a}	25.81±31.81^{ab}	22.42±29.95^{ab}	5.60±8.56^{b}
	Day 4	55.31±33.53^{a}	47.94±36.76^{a}	61.75±23.11^{a}	20.61±19.16^{b}	1.77±2.54^{b}	17.39±33.07^{ab}
	Mean	32.94±14.11^{AB}	45.62±9.20^{B}	40.77±13.57^{AB}	41.62±18.54^{A}	25.08±16.33^{A}	29.04±18.66^{A}

Values are mean ± SD, I = daily, II = once a week, and III = alternatively.
The values with similar superscripts in the column for 4 days (a or b) and for average values (A, B, or C) at each mode of application indicate no significant difference in percent repellency.
Values with different superscripts in a row for 4 days (a-b) and for average values (A–C) at each mode of application indicate significant difference in percent repellent effect between the 2 sexes at $p \leq 0.05$.

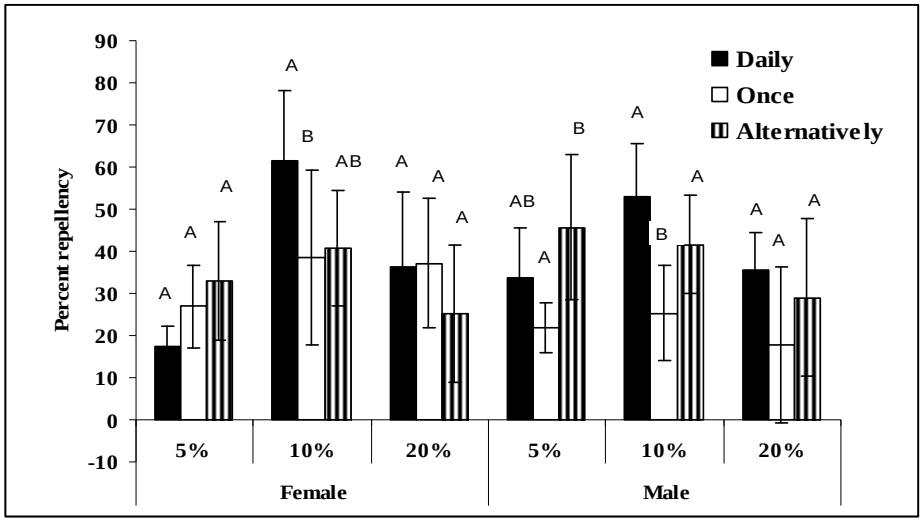

Fig. 1: Average percent repellent effect of citronella oil in *Rattus rattus* at three different concentrations and three modes of application in both female and male rats.

repellent effect was found among all the 3 modes of application in both male and female rats (Table 4, Fig. 1). In female rats, repellent effect of 20% citronella oil when applied alternatively was significantly high on day 2 (47.54%) compared to days 3 and 4. The same was, however,

significantly low on day 4 (1.77%) compared to days 1 to 3. In male rats, the percent repellency was significantly high on day 1 (36.57%) from that observed on days 2 to 4 when the 20% citronella oil was applied once a week. When the oil was applied alternatively, the percent repellent effect in male rats was found to be significantly low on day 3 (5.60%) of application compared to days 1 and 2 (Table 4).

Hile (2004) tested the repellent effects of six citronellyl compounds against European Starlings. Citronella oil has been used for over fifty years both as an insect repellent and an animal repellent (Koul *et al*., 2008). The oil of citronella provided 2h of complete repellency against mosquitoes (Trongtokit *et al*., 2005; Koul *et al*., 2008). Insect repellent formu1ations consisting of oil of citronella, spirits of camphor, oil of tar, oil of pennyroyal and castor oil have been shown to provide long-lasting protection against insects (Dover, 1930; Skinner and Johnson, 1980). Not much work has been carried out on potential of citronella oil as repellent against rodent pests. Singla *et al.* (2013b; 2014c) have reported potential of daily application of 5 and 10% eucalyptus oil in repelling away *R. rattus* of both sexes.

Conclusion: Percent repellent effect was more when the oil was applied daily and alternatively as compared to when applied once a week indicating low persistence of the repellent effect due to volatile nature of the oil. The present studies reveal higher potential of daily application of 10% citronella oil as paint in repelling away *R. rattus* of both sexes.

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REFERENCES

Barnard, D.R. 1999. Repellency of essential oils to mosquitoes (Diptera: Culicidae). *Journal of Medical Entomology*, **36**: 625-629.

Clay, D.V., Dixon, F.L. and Willoughby, I. 2005. Natural products as herbicides for tree establishment. *Forestry*, **78**: 1-9.

Dover, C. 1930. An improved citronella mosquito deterrent. *Indian Journal of Medical Research*, **17**: 961.

Hile, A.G. 2004. Avoidance of plant secondary compounds by European starlings: Citronellyls. *Crop Protection*, **23**: 973-978.

Khater, H.F. 2012. Prospects of botanical biopesticides in insect pest management. *Journal of Applied Pharmaceutical Science*, **2**: 244-259.

Koul, O, Walia, S. and Dhaliwal, G.S. 2008. Essential oils as green pesticides: Potential and constraints. *Biopesticide International*, **4**: 63-84.

Mills, E.M. and Munich, J.C. 1942. Repellents. *Pest Control*, **10**: 20-21.

Parshad, V.R. 1999. Rodent control in India. *Integrated Pest Management Reviews*, **4**: 97-126.

Singla, L.D., Singla, N. and Zhou, H. 2014a. Toxoplasmosis. pp. 148-176. **In**: *Zoonosis: Parasitic and Mycotic Diseases* (ed. S.R. Garg), Daya Publishing House, New Delhi, India.

Singla, L.D., Singla, N., Parshad, V.R., Juyal, P.D. and Sood, N.K. 2008a. Rodents as reservoir of parasites in India. *Integrative Zoology*, **3**: 21-26.

Singla, N. 2005. Role of wild rodents in the transmission of parasitic diseases to humans and domestic animals. pp. 283-293. **In**: *Compendium of Winter School on Novel Approaches for the Diagnosis and Control of Parasitic Diseases of Domestic and Wild Animals*. Department of Veterinary Parasitology, Punjab Agricultural University, Ludhiana, India.

Singla, N. and Babbar, B.K. 2010. Rodent damage and infestation in wheat and rice crop fields: District-wise analysis in Punjab State. *Indian Journal of Ecology*, **37**: 184-188.

Singla, N. and Parshad, V.R. 2005. Effects of prickly structures on burrow desertion by rodents. *Indian Journal of Agricultural Sciences*, **75**: 425-427.

Singla, N., Kaur, R. and Mahal, A.K. 2013b. Repellent effect of eucalyptus oil applied as paint against house rat, *Rattus rattus. International Journal of Advanced Research*, **1**: 220-229.

Singla, N., Singla, L.D. and Kaur, P. 2014b. Babesiosis. pp. 207-233. **In**: *Zoonosis: Parasitic and Mycotic Diseases* (ed. S.R. Garg). Daya Publishing House, New Delhi, India.

Singla, N., Singla, L.D. and Kaur, R. 2008b. Rodents as museum of helminth parasites of public health importance in Punjab, India. *International Journal of Infectious Diseases*, **12**: e381-e382.

Singla, N., Singla, L.D., Gupta, K. and Sood, N.K. 2013a. Pathological alterations in natural cases of *Capillaria hepatica* infection alone and in concurrence with *Cysticercus fasciolaris* in *Bandicota bengalensis*. *Journal of Parasitic Diseases*, **37**: 16-20.

Singla, N., Thind, R.K. and Mahal, A.K. 2014c. Potential of eucalyptus oil as repellent against house rat, *Rattus rattus. The Scientific World Journal*, Published online, *DOI: 10.1155/2014/249284.*

Skinner, W.A. and Johnson, H.L. 1980. The design of insect repellents. pp. 277-305. **In**: *Drug Design Volume 10* (ed. E.T. Ariens). Academic Press, New York, USA.

Trongtokit, Y., Curtis, C.F. and Rongsriyam, Y. 2005. Efficacy of repellent products against caged and free flying *Anopheles stephensi* mosquitoes. *Southeast Asian Journal of Tropical Medicine and Public Health*, **36**: 1423-1431.